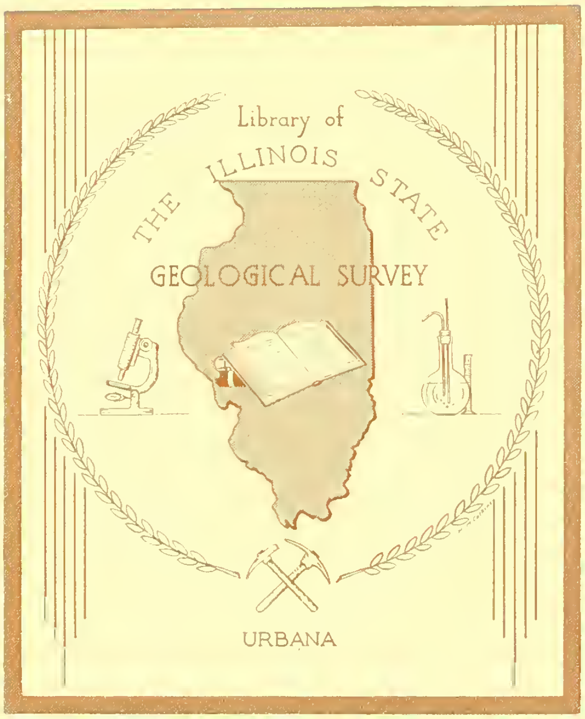
Library of
THE ILLINOIS STATE
GEOLOGICAL SURVEY
URBANA

c.2

Digitized by the Internet Archive
in 2012 with funding from
University of Illinois Urbana-Champaign

http://archive.org/details/phosphorusconten39schl

EGN 39

557
I16e
no. 39
c. 2

ENVIRONMENTAL GEOLOGY NOTES

NOVEMBER 1970 • NUMBER 39

STUDIES OF LAKE MICHIGAN BOTTOM SEDIMENTS—NUMBER FIVE

PHOSPHORUS CONTENT IN UNCONSOLIDATED SEDIMENTS FROM SOUTHERN LAKE MICHIGAN

John A. Schleicher and John K. Kuhn

ILLINOIS STATE GEOLOGICAL SURVEY

JOHN C. FRYE Chief • Urbana 61801

Library of
THE ILLINOIS STATE
GEOLOGICAL SURVEY
URBANA

STUDIES OF LAKE MICHIGAN BOTTOM SEDIMENTS - NUMBER FIVE

PHOSPHORUS CONTENT IN UNCONSOLIDATED SEDIMENTS FROM SOUTHERN LAKE MICHIGAN

John A. Schleicher and John K. Kuhn

ABSTRACT

177 samples from unconsolidated sediments on the bottom of Lake Michigan were analyzed by X-ray fluorescence spectrography for total phosphorus content; the samples, from varying depths, were taken from 56 locations. Statistical analyses of the results show that although the concentrations of phosphorus are uniformly rather low, correlations can be shown between the phosphorus content and, notably, the amounts of arsenic, iron, and organic carbon.

INTRODUCTION

One of the more common pollutants, and one in which there is a generally high interest, is phosphate. As a common constituent of fertilizers, detergents, and vegetation, it is present in nearly all drainage systems and may be responsible for excessive growth of aquatic plant life (Env. Sci. and Tech., 1970). As with some other pollutants, it is thought that an equilibrium between the phosphate content of the water and that of the bottom sediments might exist and that this equilibrium may tend to maintain a high phosphate content in the water through slow release of the excess contained in the sediments. This high level might well continue long after external sources of phosphorus pollution are controlled or eliminated. Several recent direct inquiries as to the phosphate and/or total phosphorus content of the unconsolidated sediments from Lake Michigan have prompted the publication of this preliminary report. It should be noted that, being determined by X-ray fluorescence spectrography, the phosphorus concentration is undifferentiated as to organic or inorganic form, that is, the reported values are total phosphorus concentrations calculated to P_2O_5, regardless of the form in which they are actually present in situ.

X-RAY FLUORESCENCE DETERMINATION OF PHOSPHORUS

Phosphorus content is determined by an X-ray fluorescence method similar to that used by Rose and Adler (1963). An eighth (.12500) of a gram of the ground sample is mixed with an equal amount of lanthanum oxide and one (1.00000) gram of lithium tetraborate. This mixture is placed in a graphite crucible and fused for fifteen minutes at 1000° C. The fusion bead formed is weighed to determine the fusion loss, mixed with 2 percent (by weight of pellet) Somar-Mix binder (Somar Laboratories, Inc., New York City), and ground to approximately -325 mesh. A pellet formed at 40,000 PSI pressure in a hydraulic press is used for the determination of the presence of phosphorus and other elements.

Comparison in an X-ray fluorescence spectrometer of the prepared pellet with pellets of standard materials prepared in exactly the same way will yield data from which the phosphorus concentration may be determined.

A Phillips vacuum spectrometer equipped with an ethylene diamine ditartrate crystal was used with the goniometer set at 88.81° in order to measure the intensity of the phosphorus KL_2 radiation.

It should be noted that use of the EDDT crystal requires that a correction factor for a second-order calcium radiation be applied in order to obtain accurate results.

Values determined by the preceding method have been shown, by comparison with values determined by other methods, to be accurate within the limits of most analytical methods.

RESULTS

177 samples from 56 locations in the southern half of Lake Michigan were analyzed for phosphorus content. These consisted of 2-inch and 3-inch cores and grab samples, generally taken with a Shipek sampler. The specific methods used for the sampling are discussed in Gross et al. (1970) and Shimp, Leland, and White (1970), and the complete descriptions of the cores and grab samples are given in Gross et al. (1970), Shimp, Leland, and White (1970), and Lineback, Ayer, and Gross (1970). Location, depth interval and phosphorus content are shown in table 1. Maps showing the locations of the numbered sample stations and the phosphorus content of the top interval are found as figures 1 and 2, respectively. Certain sample locations proved to be better "collectors" of certain constituents than other locations. These locations, marked in the tables with an asterisk (*), were first considered as a part of the whole set and were then computer-sorted so as to constitute a separate set of "selected" samples. The top interval and the intervals above and below 10.5 cm were examined in both the whole set and the selected set. The mean values of each of these groups of samples and their standard deviations are shown in table 2.

The phosphorus content of the subdivisions of the samples - that is, all stations and the selected samples each examined in totality and above and below 10.5 cm - were subjected to a series of correlations, both single and multiple, with various combinations of the depth in the core, the content of calcium (CaO) and iron (Fe_2O_3), the organic carbon content of the sample, and the percent of <2μ "clay-size" particles contained in the sample. The results of these correlations are shown in table 3.

TABLE 1--SAMPLE LOCATIONS AND PHOSPHORUS CONTENT

Sta. no.	Depth interval (cm)	Latitude	Longitude	P_2O_5 (%)
10	0.0 - 1.0	41° 54.39'	87° 3.19'	.11
	1.0 - 4.0			.21
11†	0.3 - 2.0	41° 58.89'	87° 6.69'	.12
	2.0 - 6.0			.19
	6.0 - 9.0			.28
	9.0 - 12.0			.18
	12.0 - 15.0			.15
	20.0 - 23.0			.13
	33.0 - 36.0			.13
17	0.0 - 3.5	41° 42.39'	87° 13.00'	.26
19	0.0 - 2.0	41° 41.79'	87° 17.79'	.03
	2.0 - 6.0			.01
	6.0 - 9.0			.06
	9.0 - 12.0			.0
	35.0 - 38.0			.02
20	0.0 - 2.5	41° 41.59'	87° 20.39'	.21
31	2.5 - 5.0	41° 49.75'	87° 33.59'	.18
32	0.0 - 0.0	41° 54.69'	87° 31.09'	.26
43	0.0 - 0.6	42° 21.79'	87° 25.19'	.02
	0.6 - 2.5			.14
	2.5 - 4.4			.11
	4.4 - 6.3			.09
44*†	0.0 - 3.0	42° 21.79'	87° 34.50'	.13
	3.0 - 6.0			.09
	6.0 - 8.0			.07
	8.0 - 10.5			.11
	10.5 - 13.5			.05
	18.5 - 22.0			.05
	33.0 - 37.0			.09
	54.0 - 58.5			.24
	84.0 - 88.0			.13
45	0.0 - 1.9	42° 21.79'	87° 39.25'	.16
	1.9 - 5.0			.07
47	0.0 - 2.0	42° 21.79'	87° 44.50'	.10
51*†	0.0 - 3.0	42° 49.89'	86° 50.50'	.32
	3.0 - 6.0			.26
	6.0 - 10.0			.21
	10.0 - 14.0			.29
52	0.0 - 0.5	42° 52.69'	86° 42.50'	.04
	0.5 - 1.5			.0
	1.5 - 3.3			.04
	3.3 - 5.0			.05
65†	0.0 - 2.0	41° 55.50'	86° 58.00'	.09
	2.0 - 5.0			.19
	5.0 - 10.0			.16
72†	0.0 - 5.0	41° 45.50'	87° 10.50'	.04
75†	0.0 - 2.0	41° 52.19'	87° 15.50'	.16

* Selected locations previously shown to have similar characteristics.

† Samples selected for surface interval examination.

TABLE 1—(Continued)

Sta. no.	Depth Interval (cm)	Latitude	Longitude	P_2O_5 (%)
75† cont.	2.0 - 6.0			.07
	6.0 - 8.0			.11
82	0.0 - 3.8	42° 9.00'	87° 26.59'	.10
87	0.0 - 3.0	41° 42.69'	87° 28.00'	.05
	3.0 - 6.0			.11
90	0.0 - 4.0	41° 41.59'	87° 23.34'	.15
	4.0 - 8.0			.12
93	0.0 - 8.0	41° 38.39'	87° 18.19'	.02
94	0.0 - 7.0	41° 38.59'	87° 10.94'	.08
101*†	0.0 - 2.0	42° 59.25'	86° 25.89'	.37
	2.0 - 4.0			.19
	4.0 - 9.0			.16
	33.0 - 37.0			.14
103	0.0 - 5.0	42° 11.19'	86° 34.09'	.39
105*†	0.0 - 3.0	42° 13.79'	86° 37.00'	.31
	3.0 - 6.0			.29
	6.0 - 9.0			.18
	27.0 - 30.0			.23
	90.0 - 94.0			.22
107	0.0 - 5.0	42° 16.69'	86° 39.69'	.29
	5.0 - 10.0			.23
	10.0 - 15.0			.17
	15.0 - 20.0			.23
	20.0 - 25.0			.24
	25.0 - 32.0			.25
	32.0 - 40.0			.16
110*†	0.0 - 3.0	42° 8.00'	86° 36.50'	.0
	3.0 - 6.0			.0
	6.0 - 9.0			.0
	9.0 - 14.0			.01
	14.0 - 18.0			.0
113*†	0.0 - 2.0	42° 9.09'	86° 43.79'	.25
	2.0 - 4.0			.28
	4.0 - 7.0			.24
	30.0 - 34.0			.18
	86.0 - 90.0			.21
115*†	0.0 - 3.0	42° 9.79'	86° 48.09'	.34
	3.0 - 6.0			.39
	6.0 - 9.0			.60
	38.0 - 44.0			.46
	98.0 - 103.0			.35
118†	0.0 - 7.0	42° 12.00'	87° 1.79'	.13
	7.0 - 16.0			.17
	16.0 - 20.0			.17
122	0.0 - 3.0	42° 2.00'	87° 6.50'	.24
	3.0 - 6.0			.08

* Selected locations previously shown to have similar characteristics.

† Samples selected for surface interval examination.

TABLE 1—(Continued)

Sta. no.	Depth interval (cm)	Latitude	Longitude	P_2O_5 (%)
122 cont.	6.0 - 9.0			.08
	16.4 - 26.5			.14
	63.0 - 74.0			.09
	0.0 - 1.5			.10
	1.5 - 3.0			.03
	3.0 - 5.0			.11
124†	9.0 - 12.0	42° 2.00'	86° 57.00'	.12
	12.0 - 15.0			.24
	15.0 - 18.0			.27
125	0.0 - 5.0	42° 2.00'	86° 52.29'	.27
	5.0 - 12.0			.35
	12.0 - 20.0			.38
	20.0 - 28.0			.24
	28.0 - 36.0			.32
	36.0 - 44.0			.36
126	0.0 - 5.0	41° 50.79'	86° 53.79'	.01
128	0.0 - 3.0	41° 44.79'	86° 59.19'	.15
135	0.0 - 2.0	41° 55.50'	87° 12.79'	.06
137	0.0 - 3.5	42° 0.00'	87° 16.19'	.10
	3.5 - 6.5			.11
140†	0.0 - 3.0	42° 6.79'	87° 21.39'	.03
	3.0 - 6.0			.0
	6.5 - 8.5			.0
	8.5 - 11.0			.0
	11.0 - 14.0			.0
	29.0 - 33.0			.0
	76.0 - 80.0			.04
141†	0.0 - 3.5	42° 11.59'	87° 18.00'	.12
	3.5 - 6.5			.11
	6.5 - 9.0			.29
	50.0 - 54.0			.08
142*†	0.0 - 4.0	42° 16.19'	87° 14.79'	.24
	4.0 - 7.0			.09
	7.0 - 10.0			.11
	10.0 - 13.0			.13
	19.0 - 23.0			.19
	51.0 - 55.0			.23
145†	0.0 - 8.0	42° 21.79'	87° 20.29'	.37
	23.7 - 31.6			.21
	67.0 - 73.8			.20
	138.3 - 152.3			.17
	162.5 - 172.3			.15
	229.0 - 257.0			.13
148†	33.5 - 39.0	42° 21.79'	87° 34.50'	.17
	75.3 - 89.9			.19
	96.6 - 120.7			.14
	193.3 - 205.5			.11
	317.7 - 325.8			.12
149	0.0 - 2.0	42° 31.69'	87° 8.75'	.24

* Selected locations previously shown to have similar characteristics.

† Samples selected for surface interval examination.

TABLE 1—(Continued)

Sta. no.	Depth interval (cm)	Latitude	Longitude	P_2O_5 (%)
149 cont.	2.0 - 5.5			.26
	5.5 - 9.0			.28
150*†	0.0 - 3.0	42° 34.20'	86° 57.10'	.29
	3.0 - 6.0			.28
	6.0 - 10.0			.32
	10.0 - 14.0			.28
	14.0 - 20.0			.36
152	0.0 - 1.0	45° 36.39'	85° 45.29'	.04
	1.0 - 2.0			.08
	2.0 - 5.0			.0
	5.0 - 10.0			.11
	10.0 - 15.0			.17
	15.0 - 20.0			.11
	30.0 - 40.0			.12
	70.0 - 80.0			.04
	100.0 - 110.0			.09
153	0.0 - 3.0	45° 25.39'	85° 14.59'	.23
	3.0 - 6.0			.23
	6.0 - 11.0			.17
	11.0 - 19.0			.26
	19.0 - 26.0			.22
	26.0 - 35.0			.17
	35.0 - 45.0			.17
	45.0 - 55.0			.17
	75.0 - 85.0			.11
241	0.0 - 4.0	43° 3.00'	86° 22.29'	.42
	4.0 - 7.0			.48
	7.0 - 10.0			.36
	10.0 - 14.0			.19
	14.0 - 18.0			.06
292	0.0 - 10.2	41° 50.00'	87° 23.75'	.05
293	20.3 - 25.4	41° 47.50'	87° 21.45'	.01
294	1.3 - 8.9	41° 50.15'	87° 20.13'	.14
295	0.0 - 7.6	41° 45.32'	87° 20.27'	.16
	0.0 - 39.0			.09
296	0.0 - 5.1	41° 44.78'	87° 16.68'	.11
	0.0 - 15.2			.14
297	0.0 - 12.7	41° 45.67'	87° 17.84'	.07
298	0.0 - 10.2	41° 50.15'	87° 16.45'	.05
299	2.5 - 7.6	41° 48.58'	87° 18.46'	.03
	12.7 - 17.8			.04
300	0.0 - 15.2	41° 45.72'	87° 18.98'	.05
301	0.0 - 5.1	41° 49.89'	87° 20.16'	.01

* Selected locations previously shown to have similar characteristics.

† Samples selected for surface interval examination.

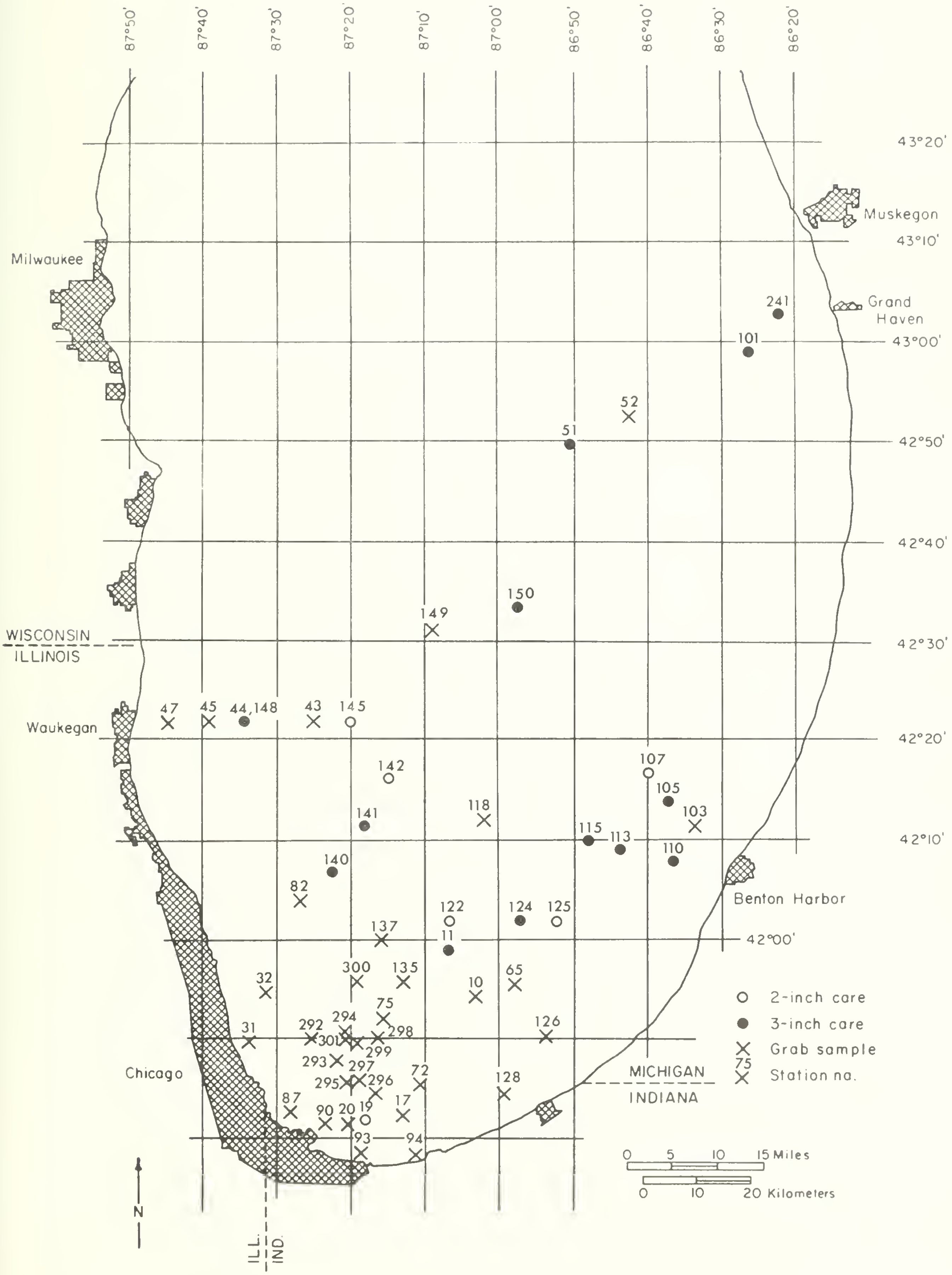

Fig. 1 - Locations of samples analyzed for phosphorus.

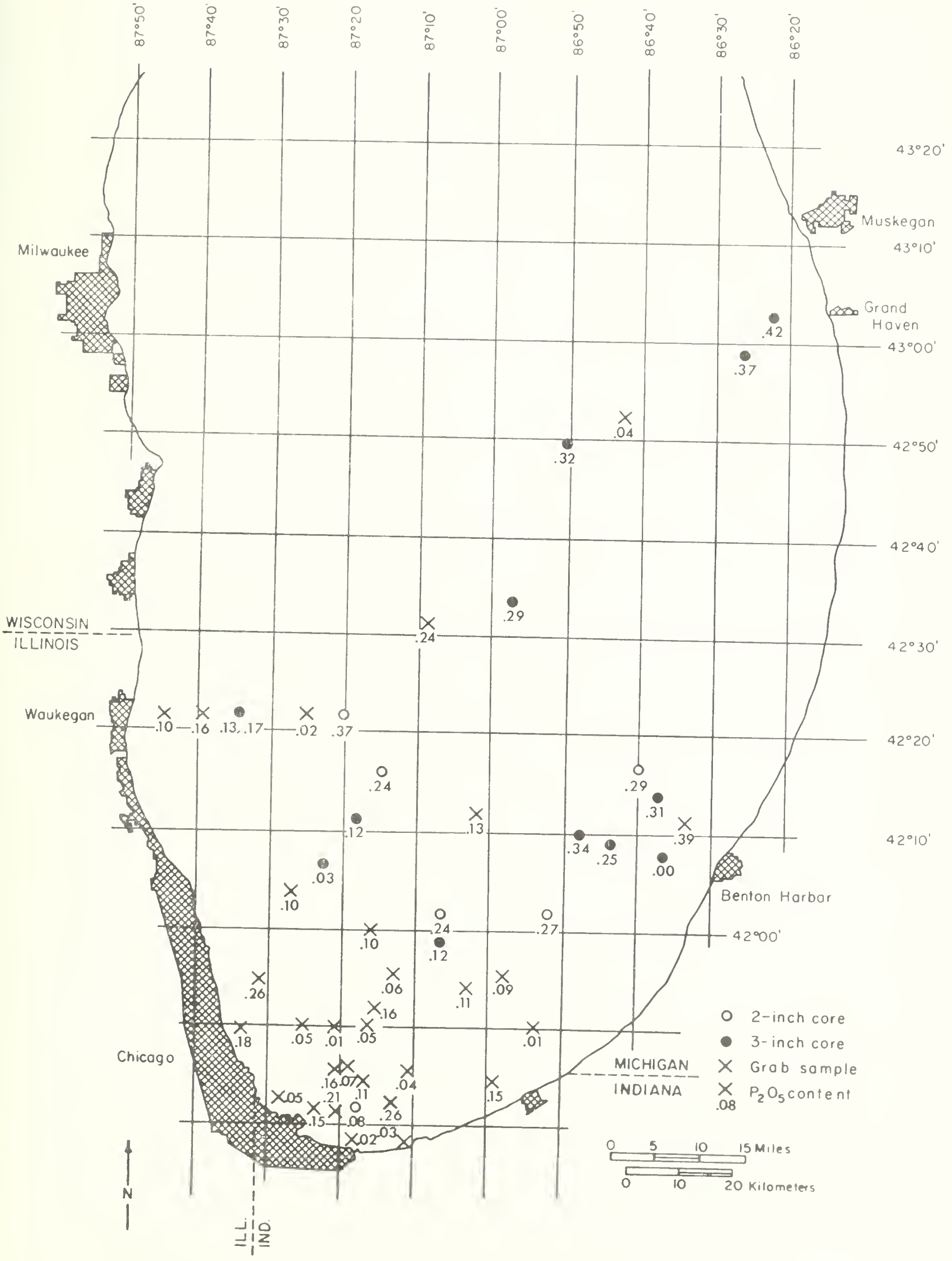

Fig. 2 - P_2O_5 content in uppermost sediment interval.

TABLE 2—MEAN P_2O_5 CONCENTRATIONS AND STANDARD DEVIATIONS

	$\bar{x}$ (percent)	Standard deviation	Sample size
Total	.17	.11	177
Top interval	.15	.11	56
Above 10.5 cm	.17	.12	104
Below 10.5 cm	.17	.09	73
Selected*	.23	.12	50
Top interval*	.25	.11	10
Above 10.5 cm*	.25	.13	27
Below 10.5 cm*	.21	.10	23
Top interval†	.19	.12	18

* Selected locations previously shown to have similar characteristics.

† Samples selected for surface interval examination.

TABLE 3—CORRELATIONS BETWEEN P_2O_5 AND VARIOUS OTHER CONSTITUENTS

P_2O_5 in ↓	Depth	CaO	Org. C	Fe_2O_3	< 2µ	Mul [1]	F-Ratio Confid. Level
Total		.04	.39	.21	.21	.43	.97
Above 10.5 cm		.22	.48	.30	.32	.53	.97
Below 10.5 cm		-.25	.24	-.03	.04	41	<.95
Total	-.04		.39		.21	.42	.97
Above 10.5 cm	.12		.48		.32	.52	.97
Below 10.5 cm	-.11		.24		.04	.25	<.95
Total			.39	.21	.21	.42	.97
Above 10.5 cm			.48	.30	.32	.52	.97
Below 10.5 cm			.24	-.03	.04	.33	<.95
Total			.39	.21		.39	<.95
Above 10.5 cm			.48	.30		.48	<.95
Below 10.5 cm			.24	-.03		[illegible]	<.95
Selected*		-.12	.43	.37	.04	.46	<.95
Above 10.5 cm*		-.07	.41	.37	.03	.40	<.95
Below 10.5 cm*		-.14	.34	.28	.33	[illegible]	<.95
Selected*	-.06		.43		.09	48	<.95
Above 10.5 cm*	-.21		.42		.03	.43	<.95
Below 10.5 cm*	.17		.34		.33	.56	<.95
Selected*			.43	.37	.09	.46	<.95
Above 10.5 cm*			[illegible]	.37	.03	[illegible]	<.95
Below 10.5 cm*			.34	.28	.33	[illegible]	<.95

[1] Mul. is multiple correlation coefficient.

* Selected locations previously shown to have similar characteristics.

In order to illustrate the relationship, if any, between depth from the sediment-water interface and the phosphorus content, a number of phosphorus distribution profiles are presented in figures 3 through 7.

Because only the upper few centimeters of sediment postdate the appearance of human civilization, correlations were run on those sediments for which top interval arsenic values were available. These stations are indicated in the tables by the sign †. The correlations of the phosphorus content of these upper intervals were computed against the content of clay, organic matter, iron (Fe_2O_3), potassium (K_2O), and arsenic (As), and multiple correlations were computed. These results are shown in table 4. Individual correlations of these top intervals and their linear regressions are shown in figures 8 through 12.

TABLE 4—CORRELATION OF PHOSPHORUS WITH VARIOUS CONSTITUENTS

(TOP INTERVAL ONLY)

<2µ Particles	Organic C	Fe_2O_3	K_2O	As	Mul.[1]	F-Ratio Confid. Level
.47	.68	.78	.55	.82	.90	99+
	.68	.78		.82	.86	95
	.68			.82	.83	95

[1] Mul. is multiple correlation coefficient.

DISCUSSION

The phosphorus content of unconsolidated sediments from Lake Michigan, as shown in table 1, is low. With the notable exception of the top interval, there seems to be very little correlation of the phosphorus with other constituents of the sediments. However, F-ratio tests of the multiple correlation coefficients show that, though of low value, the coefficients are significant for the upper segment of the total sampling and for the total sampling itself, but are of low significance for the lower segment alone, and also of low significance for all of the selected (*) samples and their divisions. Indeed, some of these latter correlations, although not obviously different in value from the correlation coefficients of the total sample, can be shown to be much less significant.

In the top sediment interval, however, a good correlation exists between phosphorus and arsenic, fairly good correlations are found with organic carbon and iron contents, and a lower correlation is found with potassium. F-ratio tests of the multiple correlations shown in table 4 show a 99+% significance level for correlation of all factors shown and an approximately 95% significance level for the remaining two more limited correlations.

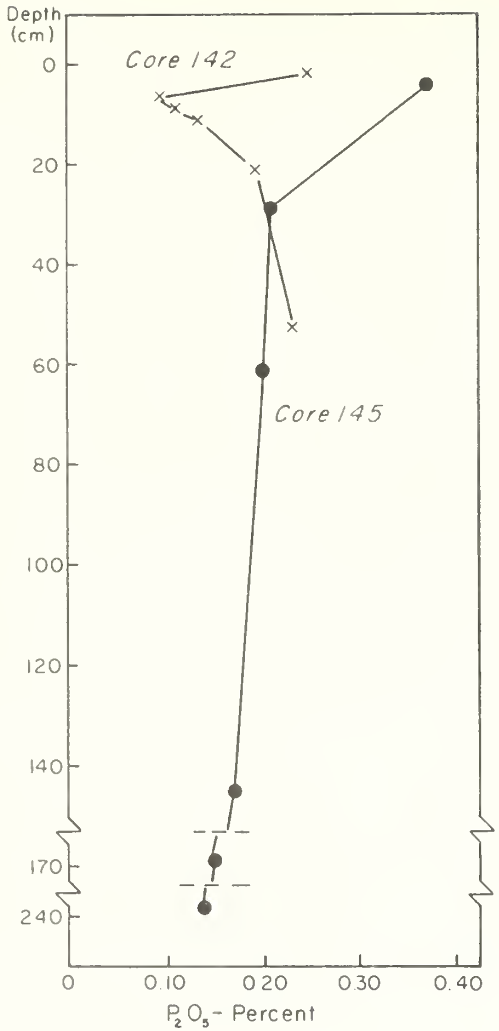

Fig. 3 - P_2O_5 in cores off Waukegan, Illinois.

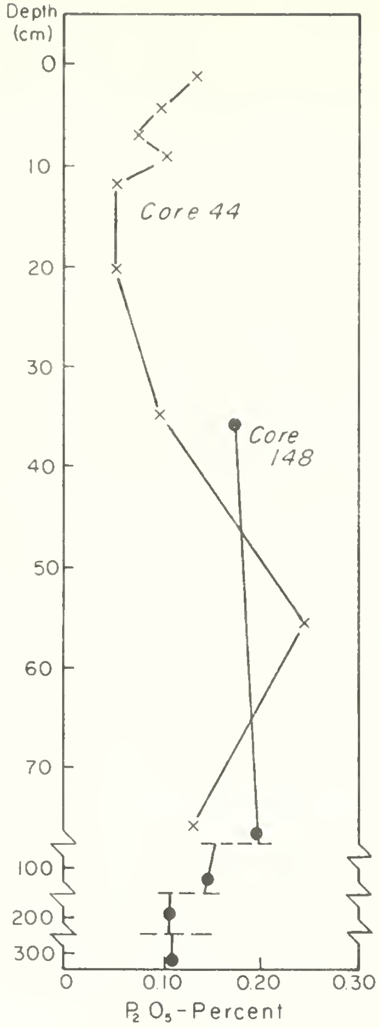

Fig. 4 - P_2O_5 in two cores from one location off Waukegan, Illinois.

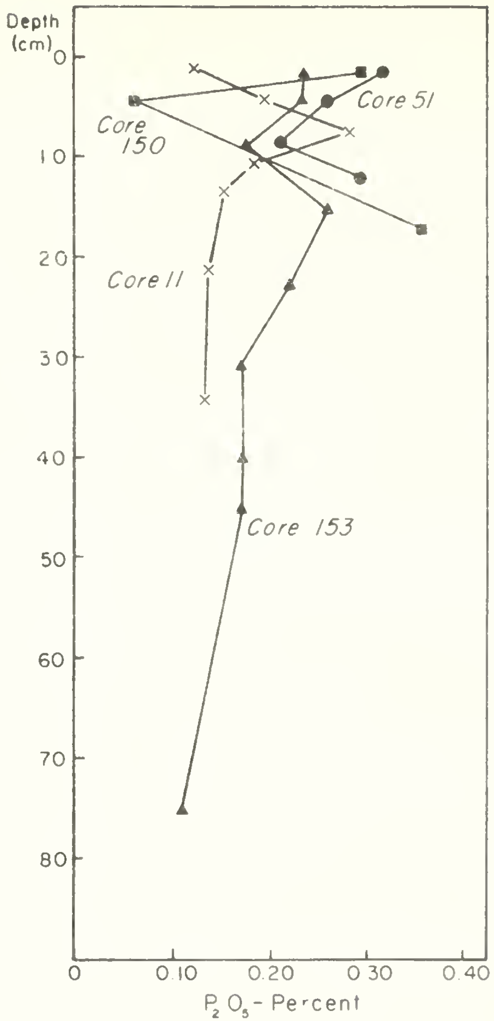

Fig. 5 - P_2O_5 in cores selected at random locations.

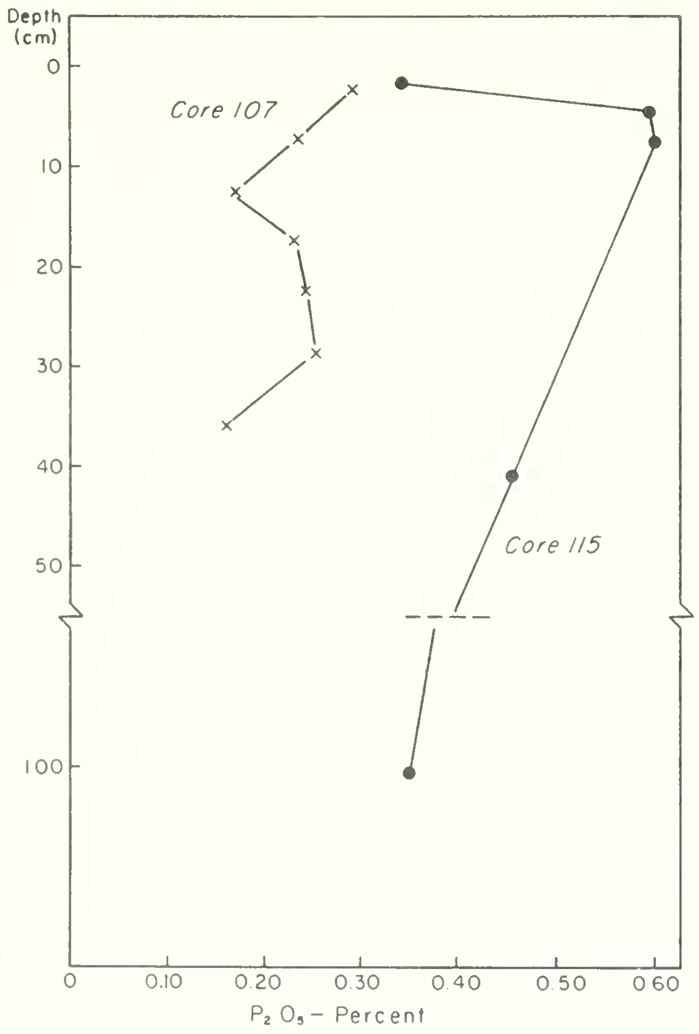

Fig. 6 - P_2O_5 in cores off Benton Harbor, Michigan.

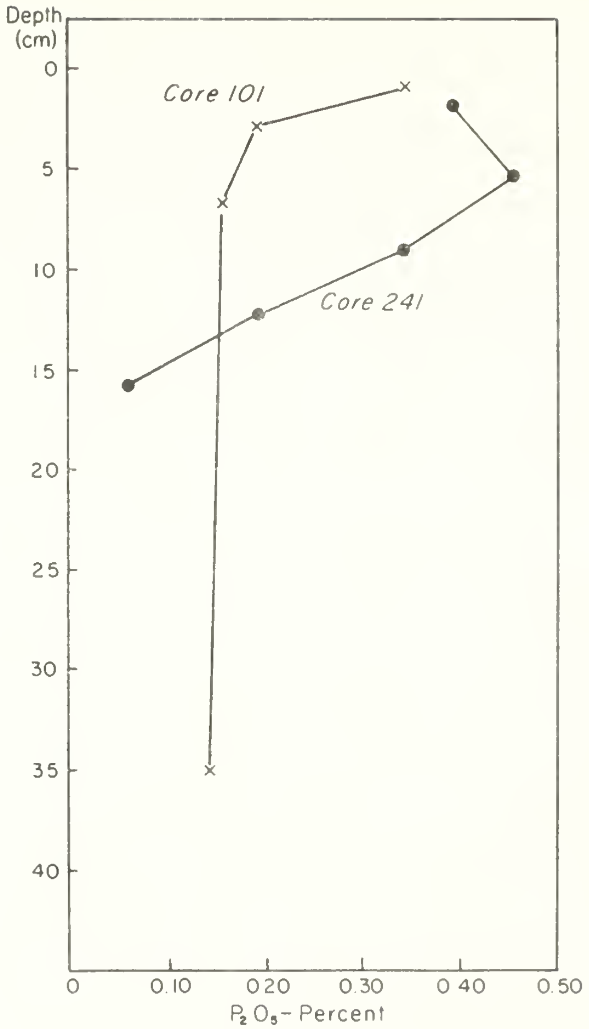

Fig. 7 - P_2O_5 in cores off Grand Haven, Michigan.

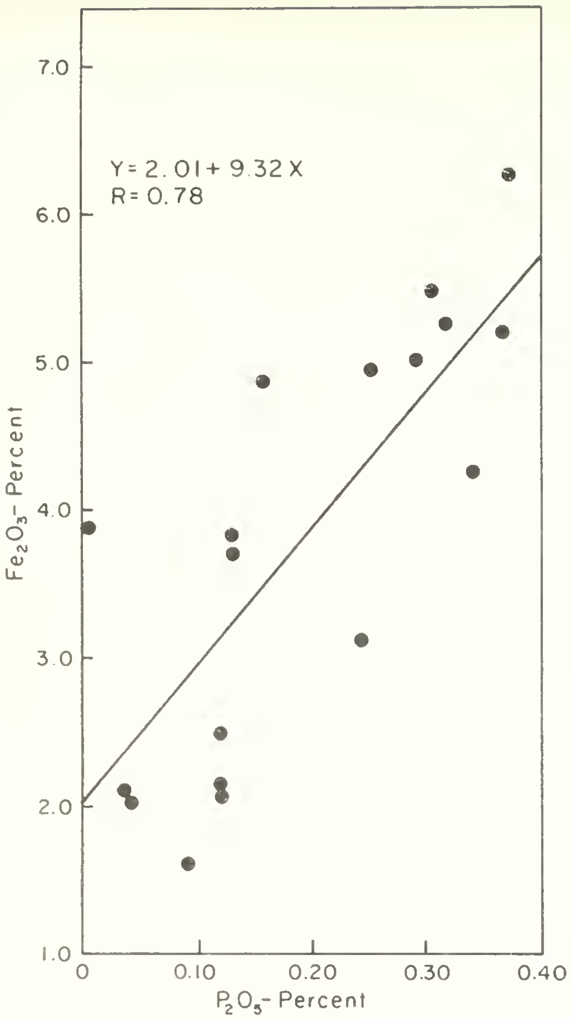

Figure 8

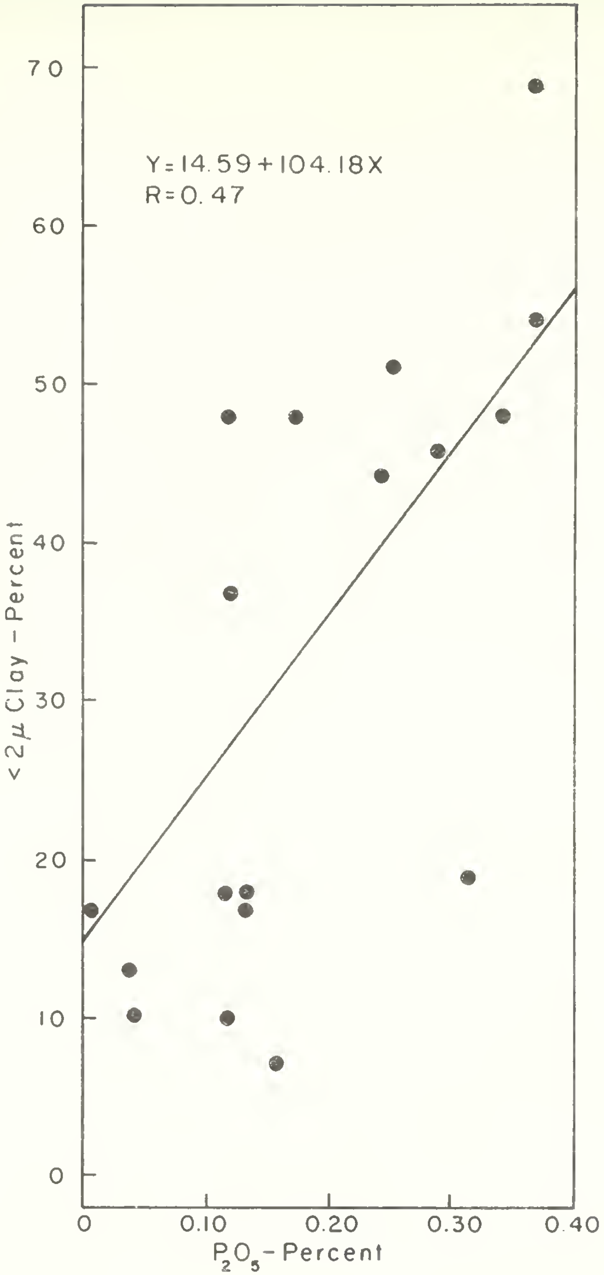

Figure 9

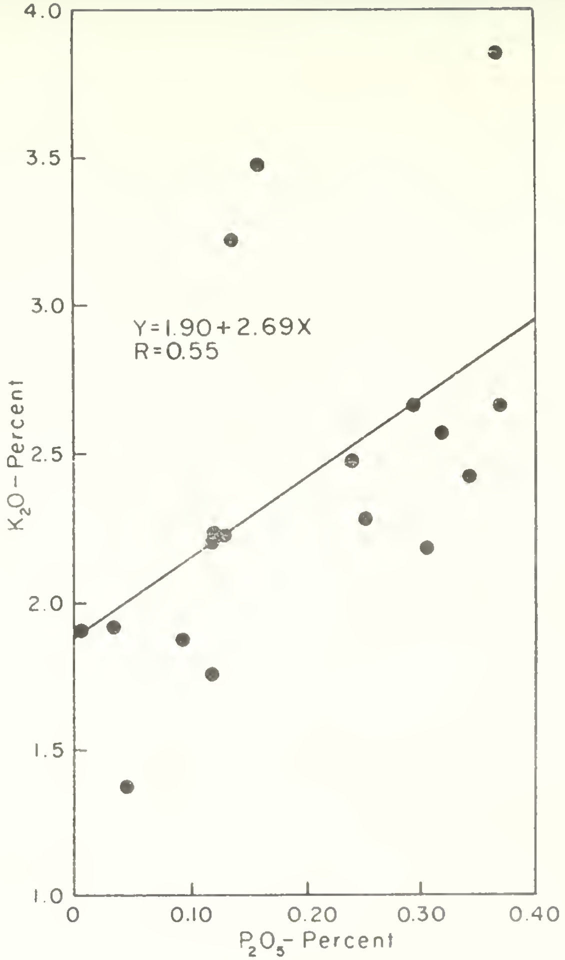

Figure 10

Figs. 8—12 - Linear regressions and correlation coefficients in top interval.

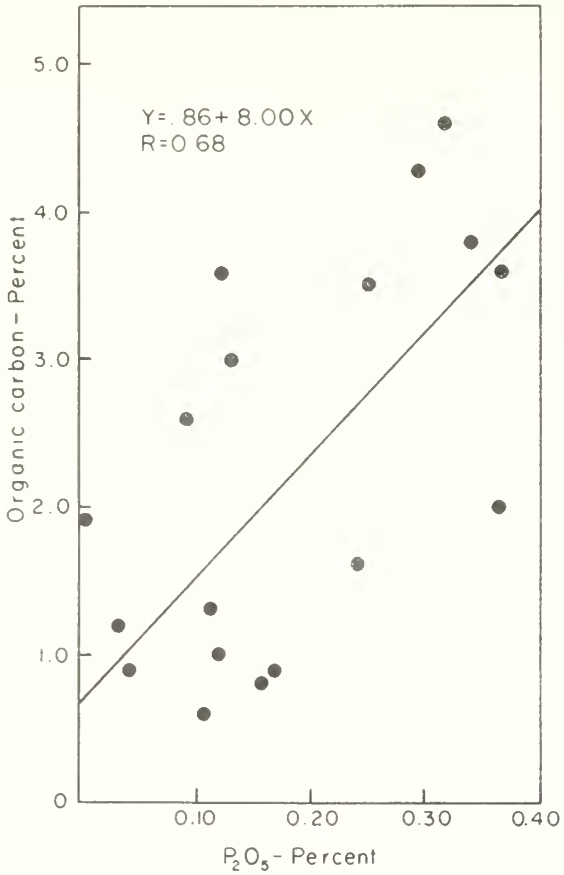

Figure 11

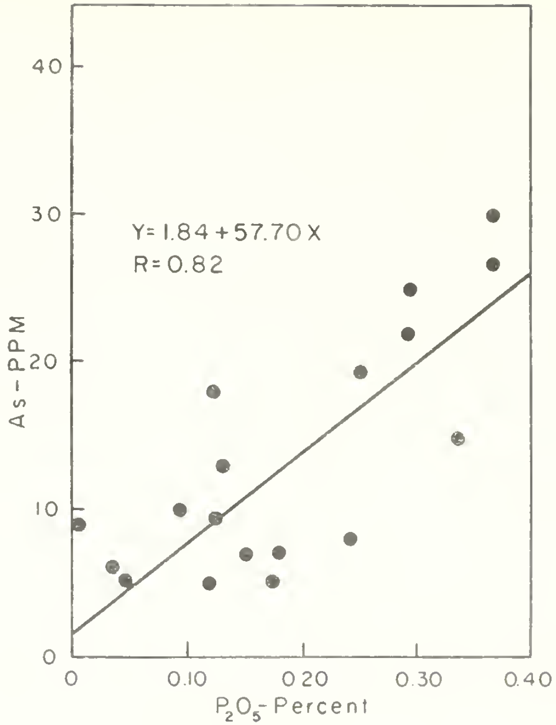

Figure 12

Figs. 8—12 - Linear regressions and correlation coefficients in top interval.

REFERENCES

Environmental Science and Technology, 1970, The great phosphorus controversy: Env. Science and Technology, v. 4, no. 9, p. 725-726.

Gross, D. L., J. A. Lineback, W. A. White, N. J. Ayer, Charles Collinson, and H. V. Leland, 1970, Studies of Lake Michigan Bottom Sediments—No. 1; Preliminary stratigraphy of unconsolidated sediments from the southwestern part of Lake Michigan: Illinois Geol. Survey Environmental Geology Note 30, 20 p.

Lineback, J. A., N. J. Ayer, and D. L. Gross, 1970, Studies of Lake Michigan Bottom Sediments—No. 3; Stratigraphy of unconsolidated sediments in the southern part of Lake Michigan: Illinois Geol. Survey Environmental Geology Note 35, 35 p.

Rose, H. J., Jr., I. Adler, and F. J. Flanagan, 1963, X-ray fluorescence analysis of light elements in rocks and minerals: Applied Spectroscopy, v. 17, no. 4, p. 81.

Shimp, N. F., H. V. Leland, and W. Arthur White, 1970, Studies of Lake Michigan Bottom Sediments—No. 2; Distribution of major, minor, and trace constituents in unconsolidated sediments from southern Lake Michigan: Illinois Geol. Survey Environmental Geology Note 32, 19 p.

ILLINOIS STATE
GEOLOGICAL SURVEY
LIBRARY

ENVIRONMENTAL GEOLOGY NOTES SERIES

* 1. Controlled Drilling Program in Northeastern Illinois. 1965.
* 2. Data from Controlled Drilling Program in Du Page County, Illinois. 1965.
* 3. Activities in Environmental Geology in Northeastern Illinois. 1965.
* 4. Geological and Geophysical Investigations for a Ground-Water Supply at Macomb, Illinois. 1965.
* 5. Problems in Providing Minerals for an Expanding Population. 1965.
* 6. Data from Controlled Drilling Program in Kane, Kendall, and De Kalb Counties, Illinois. 1965.
* 7. Data from Controlled Drilling Program in McHenry County, Illinois. 1965.
* 8. An Application of Geologic Information to Land Use in the Chicago Metropolitan Region. 1966.
* 9. Data from Controlled Drilling Program in Lake County and the Northern Part of Cook County, Illinois. 1966.
*10. Data from Controlled Drilling Program in Will and Southern Cook Counties, Illinois. 1966.
*11. Ground-Water Supplies Along the Interstate Highway System in Illinois. 1966.
12. Effects of a Soap, a Detergent, and a Water Softener on the Plasticity of Earth Materials. 1966.
*13. Geologic Factors in Dam and Reservoir Planning. 1966.
*14. Geologic Studies as an Aid to Ground-Water Management. 1967.
*15. Hydrogeology at Shelbyville, Illinois—A Basis for Water Resources Planning. 1967.
16. Urban Expansion—An Opportunity and a Challenge to Industrial Mineral Producers. 1967.
17. Selection of Refuse Disposal Sites in Northeastern Illinois. 1967.
18. Geological Information for Managing the Environment. 1967.
*19. Geology and Engineering Characteristics of Some Surface Materials in McHenry County, Illinois. 1968.
20. Disposal of Wastes: Scientific and Administrative Considerations. 1968.
*21. Mineralogy and Petrography of Carbonate Rocks Related to Control of Sulfur Dioxide in Flue Gases—A Preliminary Report. 1968.
*22. Geologic Factors in Community Development at Naperville, Illinois. 1968.
23. Effects of Waste Effluents on the Plasticity of Earth Materials. 1968.
24. Notes on the Earthquake of November 9, 1968, in Southern Illinois. 1968.
*25. Preliminary Geological Evaluation of Dam and Reservoir Sites in McHenry County, Illinois. 1969.
*26. Hydrogeologic Data from Four Landfills in Northeastern Illinois. 1969.
27. Evaluating Sanitary Landfill Sites in Illinois. 1969.
28. Radiocarbon Dating at the Illinois State Geological Survey. 1969
29. Coordinated Mapping of Geology and Soils for Land-Use Planning. 1969
30. Preliminary Stratigraphy of Unconsolidated Sediments from the Southwestern Part of Lake Michigan. 1970.
31. Geologic Investigation of the Site for an Environmental Pollution Study. 1970.
32. Distribution of Major, Minor, and Trace Constituents in Unconsolidated Sediments from Southern Lake Michigan. 1970.
33. Geology for Planning in De Kalb County, Illinois. 1970.
34. Sulfur Reduction of Illinois Coals—Washability Tests. 1970.
35. Stratigraphy of Unconsolidated Sediments in the Southern Part of Lake Michigan. 1970.
36. Geology for Planning at Crescent City, Illinois. 1970.
37. Distribution of Arsenic in Unconsolidated Sediments from Southern Lake Michigan. 1970.
38. Petrographic and Mineralogical Characteristics of Carbonate Rocks Related to Sorption of Sulfur Oxides in Flue Gases. 1970.

---

* Out of print